Air pollution study of an office building

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Air pollution study of an office building

Introduction

Indoor air quality (IAQ) refers to the physical, chemical, and biological characteristics of air in the indoor environment within a building or an institutional or commercial facility. These characteristics can be influenced by many factors, even though these buildings or facilities do not have the industrial processes and operations found in factories and plants. Factors that influence IAQ include:

- Inadequate supply of outside air
- Contamination arising from sources within the building (e.g., combustion products including carbon monoxide and environmental tobacco smoke; volatile organic compounds from building materials, fabric furnishings, carpet, adhesives, fresh paint, new paneling, and cleaning products; ozone from offiee equipment)
- Contamination from outside the building (e.g., ozone, carbon monoxide, and particulate matter) through air intakes, infiltration, open doors, and windows
- Microbial contamination of ventilation systems or building interiors

Poor IAQ may cause workers, occupants, and even the visiting public to experience a range of non-specific symptoms that affect their comfort or health. These symptoms, collectively known as sick building syndrome (SBS) or tight building syndrome, include:

- Headache
- Fatigue
- Shortness of breath
- Sinus congestion
- Eye, nose, and throat irritation
- Skin irritation
- Nausea

The symptoms of SBS tend to appear at the beginning of the week, increase each day of the week, and disappear when the person is away from the building.

Furthermore, symptoms are more frequent in the afternoon than the morning

These non-specific symptoms, however, are not necessarily due to IAQ deficiencies. They may also be caused by psychological factors and individual characteristics as well as management and organizational factors.

Although no single factor can account for SBS, inadequate ventilation was the primary problem in 53 percent of the 529 IAQ investigations conducted by the U.S. National Institute for Occupational Health and Safety (NIOSH) between 1978 and 1988.

There are also various building-related illnesses including infections such as legionellosis. Unlike SBS, building related illnesses are clinically defined with a known etiology and the symptoms are directly attributable to the environmental agents in the building air.

Indoor air pollutants may be introduced into a building from a very large and diverse range of sources. The sources can be broadly categorized as:

- Building users and their activities
- Building and furnishing materials
- Heating, ventilation, and air conditioning systems
- Outdoor air and soil

The types of contaminants that originate from each source are also many. Those of primary concern in relation to SBS are:

- Simple inorganic gases
- Volatile organic compounds
- Non-biological particles and fibers
- Bioaerosols

Despite the wide range of contaminants in the indoor air, they are present at levels much lower than are usually found in workplaces where work processes and operations are underway. Instrumentation, methods, and procedures developed for occupational hygiene sampling in workplaces may not be sensitive enough to detect the low-level contaminant concentrations in buildings. Furthermore, exposure guidelines such as ACGIH's Threshold Limit Values (TLVs®) are intended for protection or workers from exposures in the storage, handling, processing or use of substances in industrial environments, hence, they are not appropriate for assessment of IAQ.

At present, there are no IAQ exposure guidelines for assessing the acceptability of exposures to low-level contaminant concentrations in buildings The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) standard 62-1989 provides some guidance for the establishment of air quality criteria for the indoor environment. WHO lists the numerical criteria

for "concentration of concern" for some indoor air pollutants, which represent the World Health Organization (WHO) Working Group consensus at 1984 levels of knowledge. Exceeding the "concentration of concern" for a given contaminant may not necessarily imply unacceptable health risk, but it does suggest the presence of contamination source(s) in the indoor environment that warrant further investigations.

In August 1996, ASHRAE released a public review draft of Standard 62-1989. ASHRAE cautions that achieving the target indoor concentrations for all of the listed substances does not ensure freedom from sensory irritation or from all adverse health effects for all occupants. However, field experience in buildings has generally shown that air quality is perceived as acceptable by a great majority of occupants when thermal conditions meet the ASHRAE 55-1992 Standard; when outdoor ventilation rates are equal to or greater than the recommended minimum rates; when moisture levels of indoor and HVAC surfaces are low enough to prevent microbial growth; and when the concentrations of the contaminants are below the target concentration guideline levels.

As recommended in various protocols, an IAQ investigation includes a background assessment, an initial site visit, and, when necessary, a follow-up site visit. (3,4 10-13) The initial site visit is usually conducted in three separate steps: a walk-through evaluation; personal interviews; and environmental monitoring. Environmental monitoring focuses primarily on measurements of carbon dioxide level as a surrogate for evaluating ventilation efficiency, temperature, and humidity as comfort factors. Direct reading instruments and monitoring methods have been most commonly used because they are excellent screening mechanisms that provide the investigator with immediate results and feedback to anxious workers and occupants.

Materials and methods

Study Area

The study was conducted in a centrally air-conditioned ~~six~~-floor building ~~at~~ Nehru Place. Nehru Place is one of the busiest commercial centers of Delhi and thus has high traffic intensity. Each floor of the building has an area of 8000 ft^2. Based on observation about the air quality and floor occupancy, ~~Four~~ monitoring locations were selected (one outdoor and three indoor)

Three indoor monitoring locations:

- Second floor; Third floor; Fifth floor

One outdoor monitoring station: Ground (outside the building)
Air quality monitoring was done at these above-mentioned locations for thrice a week for the period of two weeks in the month of January.

Sampling

Concentration of Suspended Particulate Matter (SPM), Respirable Suspended Particulates (RSP), Sulphurdioxide (SO_2), Nitrogen dioxide (NO_2), Lead (Pb), Carbon monoxide (CO), Carbon dioxide (CO_2), Formaldehyde (HCHO) were measured. The monitoring was carried out for six days (~~Thrice a week for two~~ weeks) in the month of ~~January~~ 1999. On each day samplers at all four locations were simultaneously operated. The sampling duration for RSP, TSP, NO_2, SO_2, Formaldehyde was eight hours coincident with the working hours of the office in the building. For CO and CO_2 samples were collected intermittently in tedlar bags for 8hours and analyzed.

High volume air samplers (Envirotech make) were used to sample outdoor air with the flow rate of $1m^3$ per minute. Pre conditioned and pre weighed glass fiber filters (whatman make) were used for TSP sampling. For SO_2 and NO_2, gas samples were bubbled through the absorbing media at the flow rate of 1.5 l/m using the gaseous sampling attachment in the high volume air sampler. Indoor samplings were done with the low volume air sampler (SKC make). Low volume sampler with cyclone attachment was used for RSP sampling. Particulate matter collected on the filters were used for lead analysis.

Analysis

The samples collected on the pre weighed filters were desiccated for 24 hours and weighed on the electronic balance with a resolution of 0.00001g for SPM and RSP measurement. Some of the filters were digested using nitric acid and then analyzed in an Atomic Absorbtion Spectrophotometer for Pb analysis.

NO_2 and SO_2 were analyzed using the Jacob and Hochheiser, and West and Gaeke methods respectively. Carbon dioxide and carbon monoxide was analyzed using a GC carbon sphere packed column. GC was calibrated using standard calibration mixture.

To analyze formaldehyde, a kit of SKC make was used. This is a passive sampler and is designed for a sampling duration of 8 hours. Formaldehyde from air is absorbed into 0.05% aqueous solution of 3-methyl-2-benzothiazoline-hydrazine hydrochloride contained in a sampler at a constant flow rate. After sample collection the sample was analyzed colorimetrically.

Results and discussion

The concentration levels for carbon monoxide was BDL (below detection Limit) at all four locations on all monitored days. (The detection limit for carbon monoxide is 1ppm). This indicate the level is much lower than the respective standard.

The results of the other pollutants are presented in the following Tables. The details of monitoring and analysis protocol are given in appendices.

Table 1 Concentration (PPM) of formaldehyde (HCHO) [Sampling period = 8 h, colorimetric method]

Location		Concentration (ASHRAE standard - 0 4)					
		19/1/99	21/1/99	22/1/99	25/1/99	28/1/99	29/1/99
Indoor							
	2nd floor	-	-	-	0 012	0.014	BDL
	3rd floor	BDL	BDL	BDL	0.015	BDL	BDL
	5th floor	0 010	0 010	BDL	0 011	BDL	BDL
Out door		BDL	BDL	BDL	BDL	BDL	BDL

Concentrations of formaldehyde for most of the monitored samples are BDL (Below detection limit that is less than 0.01ppm). For all samples the level is much below the ASHRAE standard.

Table 2 Concentration (μg/m^3) of oxides of nitrogen as NO_2 [Sampling period = 8 h, modified Jacob & Hochheiser method]

Location		Concentration (ASHRAE) standard - 100, annual arithmetic mean, BDL = 3)					
		19/1/99	21/1/99	22/1/99	25/1/99	28/1/99	29/1/99
Indoor							
	2nd floor	-	-	-	22	9	18
	3rd floor	29	23	25	26	11	17
	5th floor	30	28	28	28	8	21
Out door		35	30	38	28	21	31

Table 3 Concentration (μg/m^3) of sulphur dioxide (SO_2) [Sampling period = 8 h;West and Gaeke method]

Location		Concentration (ASHRAE standard = 365 maximum, 24 h annual arithmetic mean, BDL = 3)					
		19/1/99	21/1/99	22/1/99	25/1/99	28/1/99	29/1/99
Indoor							
	2nd floor	-	-	-	27	8	7
	3rd floor	14	19	11	33	10	8
	5th floor	12	15	26	22	11	9
Out door		30	26	40	40	17	14

Table 2 & 3 reveal the level of SO_2 and NO_2 were below the threshold limit value and the concentration of these two gases have been found higher in outdoor than indoor.

Table 4 Concentration (µg/m³) of Respirable suspended particulate (RSP)
[Sampling period = 8 h; using personal sampler]

Location		Concentration (CPCB standard = 100, 24 h for residential area)					
		19/1/99	21/1/99	22/1/99	25/1/99	28/1/99	29/1/99
Indoor							
	2nd floor	-	-	-	66	77	55
	3rd floor	82	98	65	44	77	65
	5th floor	77	89	87	88	55	76

Table5 Concentration (µg/m³) of Suspended Particulate Matter (SPM)
[Sampling period = 8h; using high-volume/personal air sampler]

Location		Concentration (ASHRAE standard = 260 maximum, 24 h)					
		19/1/99	21/1/99	22/1/99	25/1/99	28/1/99	29/1/99
Indoor							
	2nd floor	-	-	-	85	106	75
	3rd floor	167	184	118	105	84	105
	5th floor	99	126	105	119	121	117
Out door		593	368	509	475	349	362

Table 4 & 5 indicate the level of RSP and SPM in all indoor samples were below the CPCB and ASHRAE standard respectively even though the level of SPM in the ambient air exceeds the CPCB standard for SPM for residential area (200 µg/m³).

Table 6 Concentration (ppm) of Lead (µg/m³) [sampling period = 8 h; high volume/personal sampler and analyzed by AAS]

Location		Concentration (ASHRAE standard = 1.5, maximum arithmetic mean over calendar qtr)					
		19/1/99	21/1/99	22/1/99	25/1/99	28/1/99	29/1/99
Indoor							
	2nd floor				BDL	BDL	BDL
	3rd floor	BDL	BDL	BDL	BDL	BDL	BDL
	5th floor	BDL	BDL	BDL	BDL	BDL	BDL
Out door		0 002	0.003	0 002	BDL	0.003	BDL

Concentration of lead in all the indoor samples were BDL and even outdoor samples were much below ASHRAE and CPCB standard (1.0 µg/m³ for 24 hours for the residential area).

Table 7 Concentration (ppm) of carbon dioxide (CO_2) [Intermittent sampling using personal sampler; GC-FID method]

Location		Concentration of CO_2					
		19/1/99	21/1/99	22/1/99	25/1/99	28/1/99	29/1/99
Indoor							
	2nd floor	-	-	-	458	402	312
	3rd floor	386	408	325	334	369	371
	5th floor	473	354	364	352	392	330
Out door		383	434	350	327	360	358

The concentration of CO_2 in all indoor samples was much below the ASHRAE standard –1000 ppm).

APPENDIX 1

Protocol for indoor SPM and RSP measurement

Pump type used	:	SKC Inc.
Filter type	:	Glass Fibre filter paper, 3.7 cm
Flow rate of pump	:	1.9 LITRE/minute
Sampling locations	:	Ground floor and 5 th floor
Sampling duration	:	8.0 hours

Procedure

I At office

1 Ensure that the pump battery is adequately charged.

2 Use a dummy filter to calibrate the pump for flow rate. Never use actual filter papers for flow rate calibration.

3 The RSP and SPM filter papers which are to be supposedly used for sampling purpose are kept in an oven at 105 $^\circ$c for an hour.

4 Transfer the papers to a desiccator after an hour and desiccate for 24 hours.

5 Weigh each paper at least twice consecutively.

6 Install the weighed papers in the filter cassettes.

II At site

1 Place samplers in position.

2 For the RSP measurements, first remove the 3rd part of the cassette and then fix a cyclone in the 2nd part. Ensure that red cap is attached to the cyclone.

3 For the SPM measurements, cyclone is not used.

4 Connect the respective filter cassettes to the pump tubing.

5 Switch off the pumps; note the starting time.

6 Switch off the pumps after 8.0 hours and note the time.

7 Detach filter cassettes from pumps.

III At Office

1 Reassemble the SPM as well as RSP filter cassettes.

2 Desiccate the filter papers for 24 hours.

3 Measure final flow rate of pumps used using dummy filter.

4 Weigh the filter papers after 24 hours and store carefully.

5 Check the battery status of the pump.

APPENDIX 2

Protocol for outdoor SPM measurement

Pump type used samplers	:	High volume samplers and Respirable dust
Filter paper used	:	Whatman's GF/A grade, (8* 10 inch)
Flow rate of pump	:	(0.7 – 1.7) m^3/minute
Sampling locations	:	Ground floor and terrace.
Sampling duration	:	8.0 hours

Procedure

I *At office*

1 Calibrate the high volume sampler and respirable dust sampler.

2 Condition the GF / A WHATMAN filter papers in an overn at 25 C for 16 hours.

3 After conditioning desiccate the papedrs for 24 hrs.

4 Weigh the papers at least twice, consecutively to get the average initial weight.

II *At site*

1 Place the HVS and RDS at their respective sampling positions.

2 Open the gable roof of the shelter of samplers and place a numbered, preweighed filter paper in position with its rough side up.

3 Replace the face plate and tighten the screws.

4 Fill the orifice meter with distilled water upto "zero" mark on meter scale.

5 Place the impingers tubes with suitable reagents in the gaseous sampling attachment unit.

6 Make proper connections of impinger outlet to individual inlets of gas manifold.

7 Connect the mains chord of the sampler to a live 220 volt A C. switch.

8 Switch on the power switch.

9 Record the sampling flow rate as indicated by the orifice meter.

10 Set the desired flow rates for gaseous sampling.

11 Let the sampler run for 8.0 hr.

12 Keep on recording the orifice meter reading and gas flow rates after every hour.

13 After 8.0 hrs, switch off the sampler using the power ON-OFF switch

14 Open the filter holder and carefully remove the filter paper.

15 Fold the paper along its length so that the soiled sides are in contact and are facing inwards.

16 Store the paper in a clean envelope.

17 Dismantle the impinger tubes and shift them to place of testing.

18 Remove sampler from sampling site to a safe storage area.

III At Office

1 Desiccate the filter paper for 24 hrs.

2 Weigh paper twice at least consecutively.

3 Do the calculations.

APPENDIX 3

Protocol for formaldehyde measurement

Principle of operation

The sample is collected by passing air through a bubbler containing MBTH solution . The sampled solution is treated with ferric chloride- sulfamic acid solution to get a blue cationic dye ,absorbance of which is measured by a digital colorimeter at 628 nm.

Appratus required:

The formaldehyde monitoring kit with all its accessories.

Sampling duration : 15 minutes

Sampler Location

1.4 meters above the ground, in center of room.

Reagents:

1 HCHO Standard solution A :: Dilute 2.7 ml of 37 % formalin solution with distilled water and standardize.

2 HCHO Standard solution B :: Dilute 1.0 ml of ' A' to 100 ml with 0.05 % MBTH solution

3 Sodium Sulfite (2N) :: Dissolve 31.5 gm of anhydrous sodium sulfite in distilled water to 250ml.

4 Hydrochloric acid , Standard solution (0.05 N) :: Dilute 4.28 ml of concentrated H Cl to 1.0 litre.

PROCEDURE:

Calibration and standardization :

Standardization of HCHO solution :

1 Place 50 ml of 2N sodium sulfite in a 125- ml flask.

2 Stir solution using a magnetic stirrer.

3 Measure and record the pH. It should be around 10 0
4 Add 25 ml of HCHO 'A' solution to the above.
5 pH should rise sharply to about 12.0.
6 Using pH meter as a continuos monitor, titrate the above solution back to its exact original pH using 0.05 N HCl. Note the volume of HCl used.
7 Do the calculations.

Preparation of standard curve :

1 Pipet 0 , 0.25 , 0.5 , 1.0 , 1.5 , 2.5 ml of HCHO 'B' solution into 50 ml volumetric flasks.
2 Dilute each to volume with 0.05 % MBTH solution.
3 Let the above flasks stand undisturbed for 1.0 hour .
4 Transfer 5.0 ml of each flask's solution to a glass- stoppered test tube and add 1.0 ml of oxidising reagent. Mix thoroughly.
5 After 12 minutes read the absorbance at 628 nm in a spectrophotometer.
6 Prepare a calibration curve by plotting absorbance versus micrograms of HCHO/ml of solution.

Sampling and Analysis :

1 Take a clean and dry passive bubbler.
2 Slide a metal clip on to the bubbler so that the prong points towards the cap of the bubbler.
3 Place 5.0 ml of 0.05 % MBTH solution in the bubbler.
4 Now place a fresh diffusion disk and then a large holed cap on the bubbler.
5 Note the starting time.

Remember :- The HCHO collection starts once the MBTH solution has been placed in bubbler.

6 Prepare a similar blank replacing the diffusion disk and holed cap with a solid cap.
7 During the sampling , the bubbler should be disk- side-down at all times.
8 To stop the sampling turn the vial upright and replace the holed cap with the solid one.
9 Note the stop time.
10 Allow the sample to stand for an hour .
11 Add 1.0 ml of the oxidising reagent to the bubbler and mix.

12 Read the absorbance after 12 minutes . Also read the blank.

13 In case the reading is more than 1.0 dilute the sample to 10 times.

14 Do the calculations .

APPENDIX 4

Protocol for sampling and analysis of Nox and SO_2

1 Take absorbing media in the impinger tubes connected to gas sampling unit in the high/low volume sampler.

2 Calibrate the flow rate of the sampler.

3 Start the sampler and measure the flow rate.

4 After every one hour measure flow rate and record it.l

5 At the end of 8 hour measure the flow rate, disconnect the tubes and keep it in icebox.

6 Analyze colorimetrically (modified Jacob & Hochheiser method for Nox) and the West and Gaeke method (SO_2).

APPENDIX 5

Protocol for sampling and analysis of O_2

1. Connect the Teddler bag to the outlet of the low volume sampler.
2. Calibrate the sampler using SKC instrument.
3. Measure the flow rate and start the sampler and let it run for first five minutes of every hour of the 8 hour monitoring duration.
4. Measure the final flow rate and record it.
5. Analyze the gases by GC-FID method for CO_2 and GC-TCD method for O_2

APPENDIX 6

ASHRAE standard for air quality

Pollutants	Indoor standards	Outdoor standards
Suspended particulate matter	-	National Ambient Air Quality Primary standard 75 µg/m^3, annual geom mean, 260 µg/m^3 maximum 24 hr Secondary standard 60µg/m^3 annual geom mean, 150 µg/m^3 maximum 24 hr
Respirable suspended particulates	-	-
Sulfur dioxide	-	National Ambient Air Quality Primary standard 80 µg/m^3 annual arithmetic mean, 365 µg/m^3 maximum 24 hr Secondary standard 1300 3 hr
Oxides of nitrogen	-	National Ambient Air Quality Primary and Secondary standard 100 µg/m^3 annual arithmetic mean
Lead	-	National Ambient Air Quality Primary and Secondary standard 1.5 µg/m^3 max. arithmetic mean over calendar qtr
Carbon monoxide	-	National Ambient Air Quality Primary standard 9 ppm (8 hr. avg.), 35 ppm 1hr. avg
Ozone	0.05 ppm	National Ambient Air Quality Primary and Secondary standard 0.12 ppm hourly avg
Formaldehyde	0.4 ppm	-
Oxygen	-	-
Carbon dioxide	-	-

APPENDIX 7

World Health Organization air pollutant guidelines

Pollutants µg/m³	Time Weighted Averages (µg = microgram, 0.000001)			
	One Hour	One Day	One Year	Other Period
Sulfur dioxide	350	100-150	40-60	500 (10 min)
Suspended Particulate Matter	100-150	40-60		
Black Smoke	150-300	60-90		230 (2% of days)
Total Suspended Lead			0 5-0 1	60 (30 min)
Carbon Monoxide	30	10[a]		100 (15 min.)
Nitrogen Oxide	400	150		190-320 (< once per month)
Ozone	150-200	100-120[a]		

[a]Eight hours.

The World Health Organization (WHO) sets guidelines for exposure to many air pollutants. Air pollution monitors measures the amount of a pollutants either continuously or by periodic observation. Measurements are usually averaged (the sum of observations is divided by the number of observations) over a certain time period. Measurements are for both acute and chronic exposure For example, a 10-minute average sulphur dioxide concentration of 500 micrograms per cubic meter (µg/m³) of air exceeds the WHO health standard for short-term exposure while an annual average concentration of 35 µg/m³ does not exceed WHO guidelines for long-term exposure. Health effects of pollutants measured are: sulfur dioxide (increased mortality, morbidity, impaired pulmonary function), lead (impaired liver and kidney functions and neurological damage), carbon monoxide (cardiovascular and neurological damage), nitrogen oxide (respiratory system inflammatory and permeability responses, lung function decrements, increases in airway reactivity), and ozone (respiratory system inflammatory and permeability responses, lung function decrements, increases in airway reactivity; eye, nose and throat irritation, headaches).

Source. World Health Organization and United Nations Environment Programme, Urban Air Pollution in the Megacities of the World (Blackwell Reference, Oxford, UK, 1992), p 12.

APPENDIX 8

Standard for criteria pollutants (CPCB, Delhi, India)

Pollutant	Time weighted average	Concentration in ambient air			Method of measurement
		Sensitive area	Industrial area	Residential, rural and other areas	
Sulphur Dioxide (SO_2)	Annual average* 24 hours**	15 µg/m³ 30 µg/m³	80 µg/m³ 120 µg/m³	60 µg/m³ 80 µg/m³	- Improved West and Gaeke Method - Ultraviolet Fluorescence
Oxides of Nitrogen (NO_2)	Annual average* 24 hours**	15 µg/m³ 30 µg/m³	80 µg/m³ 120 µg/m³	60 µg/m³ 80 µg/m³	- Jacab & Hochheiser Modified (Na-Arsenite) Method - Gas Phase Chemiluminescence
Suspended Particulate Matter (SPM)	Annual average* 24 hours**	70 µg/m³ 100 µg/m³	360 µg/m³ 500 µg/m³	140 µg/m³ 200 µg/m³	- High Volume Sampling, (Average flow rate not less than 1 1 m³/minute)
Respirable Particulate Matter (Size less than 10 µm) (RPM)	Annual average* 24 hours**	50 µg/m³ 75 µg/m³	120 µg/m³ 150 µg/m³	60 µg/m³ 100 µg/m³	- Respirable particulate matter sampler
Lead (Pb)	Annual average* 24 hours**	0.50 µg/m³ 0.75 µg/m³	1 0 µg/m³ 1.5 µg/m³	0 75 µg/m³ 1 00 µg/m³	- AAS method after sampling using EPM 2000 or equivalent filter paper
Carbon Monoxide (CO)	8 hours* 1 hour**	1 0 mg/m³ 2.0 mg/m³	5 0 mg/m3 10.0 mg/m3	2 0 mg/m³ 4 0 mg/m³	- Non dispersive infrared spectroscopy

* Annual Arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform interval

** 24 hourly/8 hourly values should be met 98% of the time in a year However, 2% of the time, it may exceed but not on two consecutive days

Note

1. National Ambient Air Quality Standard The levels of air quality necessary with an adequate margin of safety, to protect the public health, vegetation and property.
2. Whenever and wherever two consecutive values exceed the limit specified above for the respective category, it would be considered adequate reason to institute regular/continuous monitoring and further investigation
3. The State Government/State Board shall notify the sensitive and other areas in the respective States within a period of six months from the date of Notification of National Ambient Air Quality Standards.

APPENDIX 9

Indoor and outdoor sources of pollution

Pollutants	Source
Predominantly outdoor	
Sulphur oxides	Coal and oil combustion, smelters
Ozone	Photochemical reactions
Lead, manganese	Automobiles, smelters
Calcium, chloride, silicon, cadmium	Soil particulates and industrial emission
Organic substances	Petrochemical solvents, vaporization of unburnt fuels
Indoor and outdoor	
Nitrogen oxides	Fuel combustion
Carbon monoxide	Incomplete fuel combustion
Carbon dioxide	Fossil fuel combustion, metabolic activity resuspension, condensation of vapours and combustion products
Suspended particulate matter	Resuspension, condensation of vapours and combustion products
Organic substances	Petroleum products, combustion, paint, metabolic action, pesticides, insecticides and fungicides
Ammonia	Metabolic activity, cleaning products and agriculture
Predominantly indoor	
Radon	Building materials (concrete, stone), water and soil
Formaldehyde	Particle board, insulation, furnishings, tobacco smoke
Asbestos, mineral wools, synthetic substances	Fire retardant, acoustic, thermal or electric insulation
Organic substances	Adhesives, solvents, cooking, cosmetics
Aerosol of nicotine and other organic substances	Tobacco smoke
Mercury	Fungicides in paints, spills in dental-care facilities or laboratories, thermometer breakage
Aerosols of varying composition	Consumer products
Viable organisms	Infected organisms
Allergens	House dust, animal debris